I hereby certify that this correspondence is being deposited with the U.S. Postal Service with sufficient postage as First Class Mail, in an envelope addressed to: Commissioner for Patents, Alexandria, VA 22313, on the date shown below.

Dated: 9/24/04 Signature: David T. Yang

OIPE SEP 27 2004 PATENT & TRADEMARK OFFICE

BEST AVAILABLE COPY

Docket No.: 535352000500
(PATENT)

IN THE UNITED STATES PATENT AND TRADEMARK OFFICE

In re Patent Application of:

Reamon et al.

Application No.: 09/705,134

Group Art Unit: 2817

Filed: November 2, 2000

Examiner: B. Lee

For: ON-CHIP MULTILAYER METAL SHIELDED TRANSMISSION LINE

DECLARATION OF PRIOR INVENTION

PURSUANT TO 37 C.F.R. 1.131

Commissioner for Patents
Alexandria, Virginia 22313-1450

Dear Sir:

We the undersigned, , declare as follows:

1. We are the inventors of the above-referenced patent application, and are familiar with its contents.

2. Prior to at least December 30, 1998, we had formed a complete and operative idea of a point of interest spatial search method and system. At our direction, Leonard A. Alkov (Reg. No. 30,021) of Raytheon Company prepared a patent application disclosing this invention, the present application was filed in the United States Patent and Trademark Office on November 2, 2000. The following paragraphs summarize the documents attached to this declaration, which are submitted as evidence of these statements. All of the attached documents were prepared in the U.S.

3. *Exhibit A* is a photocopy of laboratory notes dated between December 6, 1998 to December 9, 1998, by one of the inventors detailing various aspects of an on-chip multilayer metal shielded transmission line. As shown in the notes, calculations and drawings were generated for practicing a shielded monolithic transmission line having particular dimensions and spacings.

4. *Exhibit B* is a photocopy of an inventor disclosure that was submitted by the named inventors to the Raytheon company, detailing certain final aspects of the invention. The inventor disclosure was reviewed, revised, and placed into final form for filing with the USPTO.

5. We have reviewed U.S. Patent No. 6,133,621, by Gaibotti et al., provided by the U.S. Patent Office accompanying the Office Action mailed on March 24, 2004. Gaibotti was filed in the U.S. on December 30, 1998, and issued on October 17, 2000. Contained therein is an integrated shielded connection for use inside an integrated circuit.

6. The subject matter we desire to claim does not correspond to a lost count in an interference and is not otherwise barred to the applicants. We do not believe that the invention was in public use or on sale in this country, patented or described in a printed publication in this or any foreign country more than one year prior to the filing of this application. We never abandoned the invention before the filing date of this application.

7. We hereby declare that all statements made herein of our own knowledge are true and that all statements made on information and belief are believed to be true. We declare that all these statements were made with the knowledge that willful false statements and the like so made are punishable by fine or imprisonment, or both, under Section 1001 of Title 18 of the United States Code, and that such willful false statements may jeopardize the validity of the application, any patent issuing thereon, or any patent to which this verified statement is directed.

9/22/04	
Date	Alan E. Reamon
09/22/04	
Date	Lloyd F. Linder
9/22/04	
Date	Erick M. Hirata
Date	Nick Elmi

Heei knows someone ...
but has no experience + he probably doesn't want to come to Raytheon
Heei said he left because he got no respect from anyone

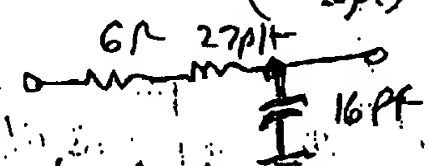
Sat. 12/05/98 (0.8um)(X MΩ/μ)
what is the current handling capability for the metals?

based on Mik's calculations
$L = .266 \text{ ph}/\mu m$
$C = .163 \text{ fF}/\mu m$

want $\frac{\omega_0}{2\pi} = f_0 = 150\text{GHz} = \frac{1}{2\pi\sqrt{LC}}$

$\sqrt{LC} = \frac{1}{2\pi(150\text{GHz})} \Rightarrow LC = 1.125\times10^{-24}$ 4 mil

for 100μ, $L = 26.6\text{pH}$ $C = 16.3\text{fF}$
$45\text{m}\Omega/\square$ $\left(\frac{100\mu}{0.8\mu}\right)\left(\frac{45\text{m}\Omega}{\square}\right) = 5.6\Omega$ for 3u wide line $R_s = 1.5\Omega$

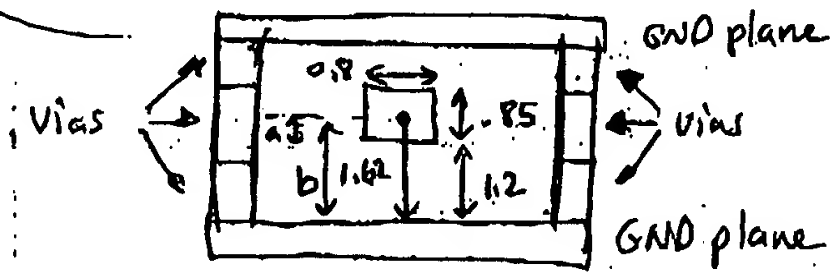


don't think we can use 0.8μm anyways due to current

TIA cell ≈ 1.3 × 1.6 mil = 2.1 mil²
Sun. 12/06/98 Don't see any caps on TIA layout
questions for TIA:
1) what is temp room or cryo?
2) do they have cryo models? in the application What does β do?
3) what's their resistor width? current density?

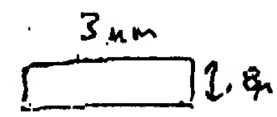
the conductor dimensions are .8x.8 so
a circle of diameter .8µm is close to that.

Nick assumed that the stripline structure was basically a coax (that's why he said that we should put a wall around the conductor:



$a = .42\ \mu m$
$b = 1.62\ \mu m$

(*) All calculations assume 0.8µm wide line



$\mu_m = \mu_r \mu_0 \quad \mu_r = 1$ glass - assumed

distributed inductance ⇒

$L = \frac{\mu_m}{2\pi} \ln\left(\frac{b}{a}\right)$ b, a defined above

$L = \frac{\mu_0}{2\pi} \ln\left(\frac{b}{a}\right) \qquad \mu_0 = 4\pi \times 10^{-7}\ \frac{\text{Henries}}{\text{meter}}$

$$= \left(4\pi \times 10^{-7}\ \frac{H}{m}\right)\left(\frac{1}{2\pi}\right)\left(\frac{1m}{10^6\ \mu m}\right) \ln\left(\frac{1.62}{.42}\right)$$

$$= \left(2 \times 10^{-13}\ \frac{H}{\mu m}\right)(1.34) = 2.68 \times 10^{-13}\ \frac{H}{\mu m} = \boxed{268\ \frac{fH}{\mu m}}$$

now this equation assumes:
1) circular conductors for all planes
2) $\mu_r = 1$ → assumption is the material in the interconductor space of the coax line has the magnetic properties of free space.

characteristic impedance

$Z_0 =$ [redacted] $\sqrt{\frac{\mu_m}{(2\pi)^2 \varepsilon'}} \left[\ln\left(\frac{b}{a}\right)\right] \overset{\text{or}}{=} \frac{138\sqrt{\mu_r}}{\sqrt{\varepsilon_r}} \log_{10}\left(\frac{b}{a}\right)$

$= \boxed{40.96 \text{ ohms}}$

Nick verified this from a chart for a symmetric stripline w/ finite conductor thickness. So these approximations seem to be valid.

distributed capacitance

$\varepsilon' = \varepsilon_r \varepsilon_0$

$C = \frac{2\pi\, \varepsilon_r \varepsilon_0}{\ln b/a}$ F/m • $\varepsilon_0 = 8.85 \times 10^{-12}\ \frac{F}{m}$

$\varepsilon_r = 3.9$

$$C = \frac{2\pi(3.9)(8.85 \times 10^{-12})}{\ln\left(\frac{1.62}{.42}\right)}\ F/m = \boxed{.161\ fF/\mu m}$$

therefore, his assumption of a circular coax was valid to approximate the rectangular conductor

distributed conductance

$G = \omega C \tan\delta$ $\qquad \omega = \overset{1.5}{2\,GHz}$

glass is assumed, so loss tangent $= \tan\delta = .006$

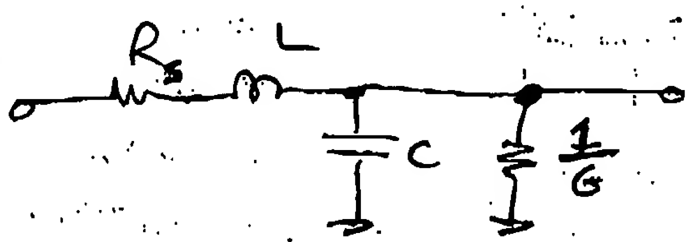
@ 1.5 GHz, $\boxed{G = (2\pi)(1.5\times10^9)(.006)(.161\,fF/\mu) = 9.1\,n\mho/\mu m}$

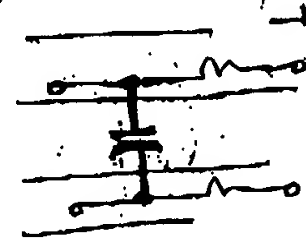
@ 2 GHz, $\boxed{G = 12.1\,n\mho/\mu m}$

unit Resonant frequency $\rightarrow$ $f_{\text{unit length}} = \dfrac{1}{2\pi\sqrt{LC}} = \dfrac{1}{2\pi\left[\sqrt{(.161\,fF/\mu m)(268\,fH/\mu m)}\right]}$

$= \boxed{24\,(THz\,\mu m)\ \text{unit length}}$

$f_{Res} = \left[f_{\text{unit length}}\right]\cdot\left(\dfrac{1}{\sqrt{L^2}}\right)$ L is in µm





→ do sidewall cap for coupling, don't know about mutual inductance.

$R_s = \dfrac{1}{\sigma\delta_s}\,\dfrac{1}{2\pi b}\left(1+\dfrac{b}{a}\right)$ Ω/meter^2

σ = conductivity of aluminum $= 3.54\times10^7\ \dfrac{\mho}{\text{meter}}$

$\delta_s = \sqrt{\dfrac{2}{\omega\mu_m}}$ $\qquad \omega$ = frequency of operation

as $\omega\downarrow$ $\delta_s\uparrow$ so used 2.0 GHz (less damping)

$\delta_s = \sqrt{\dfrac{2}{(2\times10^9 s^{-1})(1)(3.5\times10^7 \frac{\mho}{m})(4\pi 10^{-7})}}$

$= 1.9\times10^{-6}\,m$

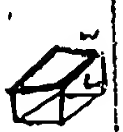
distributed resistance → $R_s = \dfrac{1}{\sigma}\cdot\dfrac{\sqrt{2\pi f\mu_0}}{\sqrt{2}}\,\dfrac{1}{2\pi b}\left(\dfrac{a+b}{a}\right)$

$= \dfrac{\sqrt{\cancel{2}\pi f\mu_0}}{\sqrt{\cancel{2}\sigma}}\,\dfrac{1}{\sqrt{4\pi}}\,\dfrac{1}{b}\left(\dfrac{a+b}{a}\right) = \sqrt{\dfrac{f\mu_0}{4\pi\sigma}}\left(\dfrac{a+b}{ab}\right)$

$= \sqrt{\dfrac{(2\times10^9 Hz)(\cancel{4\pi}\times10^{-7}\,\frac{H}{m})}{\cancel{4\pi}(3.54\times10^7\,\mho/m)}}\ \dfrac{(.42+1.6)}{(.42)(1.62\,\mu m)}$

$= \left(2.38\times10^{-3}\,\dfrac{\Omega}{m}\right)\left(\dfrac{1m}{10^6\mu m}\right)\left(\dfrac{2.97}{\mu m}\right) = \boxed{7.1\,n\dfrac{\Omega}{\mu m^2}}$ $\ast(W)(L)$

↳ for 100µ long, 3µ wide



$\rho L/A$ $\qquad$ 95Ω/□ M3. Does this agree?

$\delta_s = 1.90\,\mu m$ $\quad f = 2\times10^9 s^{-1}$ $\quad \lambda_0 = .15\,m$

$\tan\delta = .006$

$\lambda_0 = c/f$

insertion loss

$\alpha = \alpha_{conductor} + \alpha_{dielectric}$

$\alpha_{dielectric} = 27.3 \dfrac{\sqrt{\varepsilon_r}}{\lambda_0} \tan\delta$

$\alpha_{dielectric} = \dfrac{27.3(\sqrt{3.9})(.006)\ 1m}{.15m\ (10^6\mu m)}$

$= 2.15\times10^{-6}\ dB/\mu m$

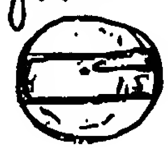
$\dfrac{b}{a} = \dfrac{1.62}{.42} = 3.9$

$\alpha_{conductor} = \dfrac{13.6\,\delta_s \sqrt{\varepsilon_r}\,(1 + b/a)}{\lambda_0\, b\,[\ln(b/a)]}$

$\alpha_{conductor} = \dfrac{(13.6)(1.90\mu m)(\sqrt{3.9})(1+3.9)(1m)}{(.15m)(1.62\mu m)[\ln(3.9)](10^6\mu m)} = 0.000755\ dB/\mu m = 7.55\ dB/cm$

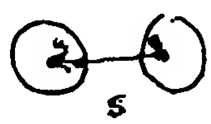
units are dB/m according to Nick

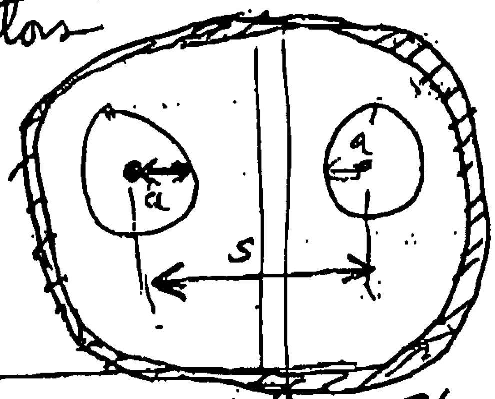
for this



parallel conductor

this analysis may not be valid.





assume same approximations as before

for

$a = 1.5\,\mu m$

$s = 3.8\,\mu m$

$\frac{s}{2a} = 1$

$C = \dfrac{\pi\,\varepsilon_0\varepsilon_r}{\ln\left[\frac{s}{2a} + \sqrt{\left(\frac{s}{2a}\right)^2 - 1}\right]}\ F/m$

$= \dfrac{(\pi)(3.9)\ 8.85\times10^{-12}(F/m)}{\ln\left[\frac{3.8}{3.0} + \sqrt{\left(\frac{3.8}{3.0}\right)^2 - 1}\right]} = 151\times10^{-12}\ F/m$

$= .151\ fF/\mu m$

$L = \dfrac{\mu_m}{\pi}\cosh^{-1}\dfrac{s}{2a} = \dfrac{\mu_m}{\pi}\ln\left[\frac{s}{2a} + \sqrt{\left(\frac{s}{2a}\right)^2 - 1}\right]\ \frac{H}{m}$

$= \left(4\times10^{-7}\frac{H}{m}\right)\left(\frac{1m}{10^6\mu m}\right)\left(\frac{1}{\pi}\right)\ln\left[\frac{3.8}{3.0} + \sqrt{\left(\frac{3.8}{3.0}\right)^2 - 1}\right]$

$= 91\ fH/\mu m$

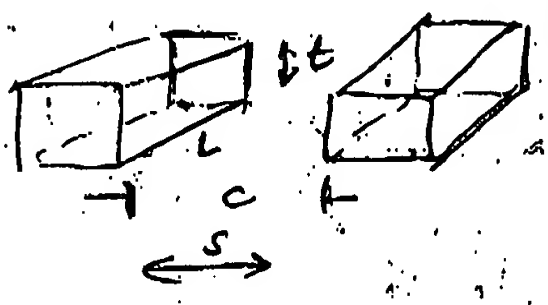
$k_e' = \varepsilon_r\varepsilon_0/\varepsilon_0$

$Z_0 = \dfrac{120}{\sqrt{\varepsilon_r}}\ln\left[\frac{s}{2a} + \sqrt{\left(\frac{s}{2a}\right)^2 - 1}\right] = \dfrac{120}{\sqrt{3.9}}\ln\left[\frac{3.8}{3.0} + \sqrt{\left(\frac{3.8}{3.0}\right)^2 - 1}\right]$

$Z_0 = 43\,\Omega$

Nick – coupling has to [redacted] be measured.

Nick says if that the conductors are spaced far enough apart, there is no mutual inductance only mutual capacitance



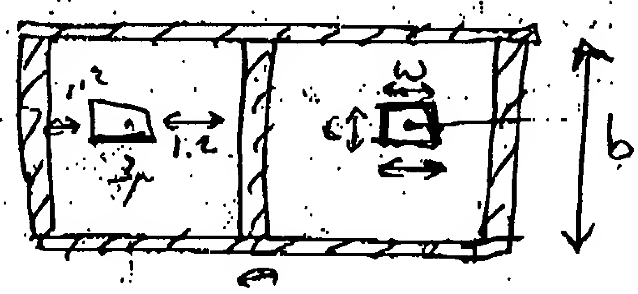
$\frac{\varepsilon_0 A}{d} = C_{\text{coupling between conductors}}$

$A = tL \qquad C = \left(\frac{\varepsilon_0 \varepsilon_r t L}{s}\right)$

list of programs I'm working on to Bob Ferriera. Sent him email.

1) Ultracomm
2) ACS
3) Bidding – Expense APD ROIC → due Dec. 15th
4) RF Switch
5) ADRT → design review this Thursday. I need to do viewgraphs
6) INX Risk Reduction
7) Support ROAY, SW ABs, new business opportunities
8) SiGe process characterization

best way to go →



nick's reference for above for coupled conductors

→ for 2 parallel conductors

$$Z_0\sqrt{\varepsilon_r} = \frac{94}{x(w/b) + \frac{1}{\pi}F(x)}$$

$$F(x) = \frac{(x+1)^{x+1}}{|x-1|^{x-1}} \qquad x = 1 - t/b$$

$t = .85$
$w = 3$ $\quad b = 3.2$

$x = 1 - \frac{.85}{3} = .72$ $\qquad F(x) = \frac{(1.72)^{1.72}}{|(.72-1)|^{.72-1}}$ = this doesn't work out unless abs. value

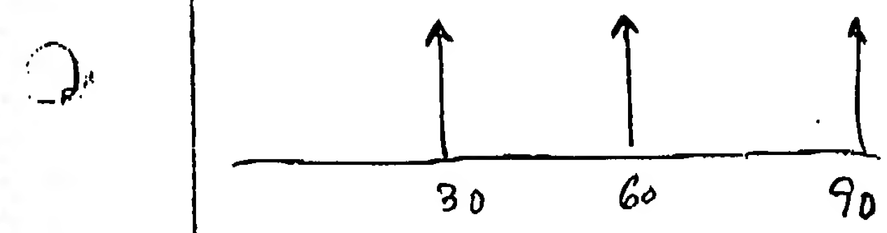
$F(x) = 3.6$

$Z_0\sqrt{\varepsilon_r} = \frac{94}{\frac{1}{\pi}(3.6) + (.72)\left(\frac{3}{3.2}\right)}$

$\boxed{Z_0 = 26.1\Omega}$ see 3 pages over

$Z_0 = \sqrt{L/C}$

w = width of conductor
t = thickness of the conductor
b = distance bt. GND conductors



Cliff: has to drive large cap @ the output @ the mixer. Remove it, & see if it's a problem. PAOS is still a problem but uses same one as the LO(?)

from one of Nick's books

for single layer dielectric
$\frac{t}{b} = \frac{.85}{3.2} = .265$

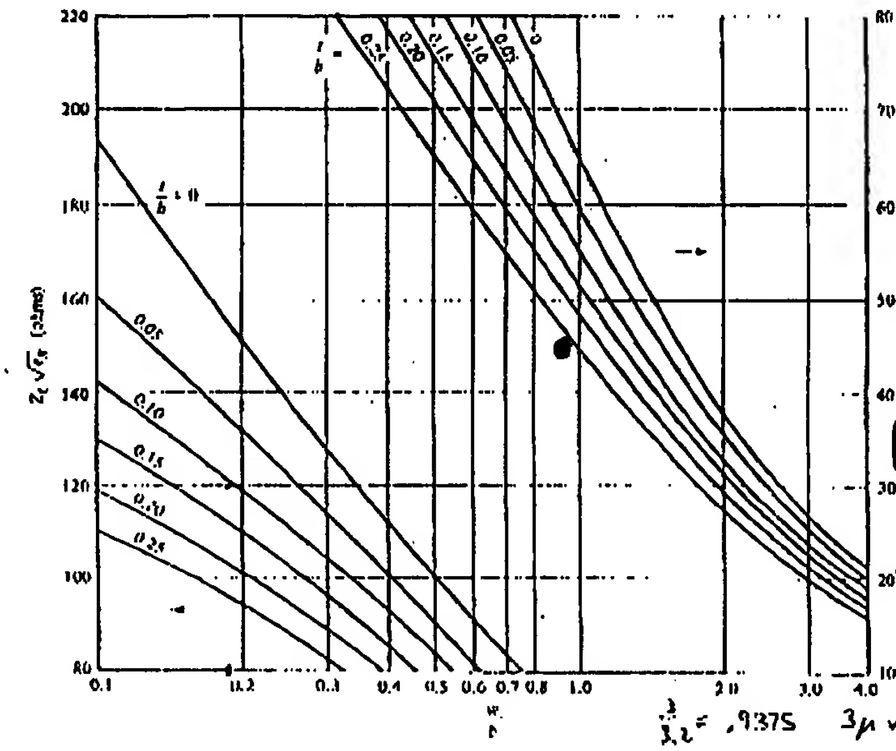
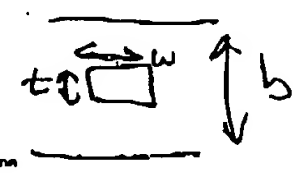


Figure 5-8 Characteristic impedance data for stripline. A nonmagnetic dielectric is assumed ($\mu_R = 1.0$). Also $a \gg w$ and $a > 2b$. (From S. Cohn, Ref. 5-14; © 1955 IRE now IEEE, with permission.)

$$Z_0 = \frac{\sqrt{\mu_R \epsilon_R}}{3 \times 10^8 C'} \text{ ohms}$$

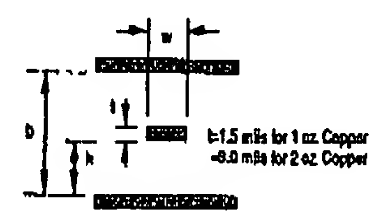
C per unit length of a stripline

→ this is close to the 26Ω I calculated for general case of t/b, w/b



DCD gave me this. R.N.'s EXCEL spreadsheet for Z_0 calculations.

see what Robert's program spits out



er (board dielectric)	3.90	4.70	4.79
h (dielectric height)	1.2	1.2	1.2 mils
w (line width)	3	3	3 mils
t (Copper thickness)	0.85	0.65	0.85 mils 1/2 oz. Cu
OTOROLA MECL SYSTEM DESIGN			
w/(b-t) < 0.35	8.57	8.57	8.57
t/b < 0.25	0.71	0.71	0.71
Motorola Equation Valid?	Maybe Not	Maybe Not	Maybe Not
zo (Motorola MECL)	19.51	17.77	17.59 •
S.B. Cohn, J.F. White			
=w/(2*b) <0.35 Narrow, >= 0.35 Wide	1.25		
White,Cohn Narrow or Wide?	Wide		
zo (White,Cohn)	$\boxed{23.74}$		

Stripline For 75Ω Calculation

er (board dielectric)	4.47	4.70	4.79
h (dielectric height)	31	31	31 mils
w (line width)	9	9	9 mils
t (Copper thickness)	0.75	0.75	0.75 mils 1/2 oz. Cu
OTOROLA MECL SYSTEM DESIGN			
w/(b-t) < 0.35	0.30	0.30	0.30
t/b < 0.25	0.02	0.02	0.02
Motorola Equation Valid?	OK	OK	OK
zo (Motorola MECL)	76.89	74.95	74.31 •
S.B. Cohn, J.F. White			
=w/(2*b) <0.35 Narrow, >= 0.35 Wide	0.15	0.15	0.15
White,Cohn Narrow or Wide?	Narrow	Narrow	Narrow
zo (White,Cohn)	77.47	75.61	74.77 •

OTHER COMBINATIONS OF (h,w) (21,6), (24,7), (27,8), (31,9), (34,10)

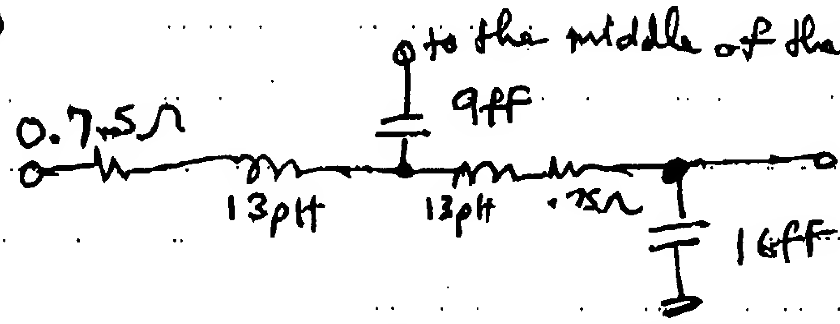
Stripline For 50Ω Calculation

er (board dielectric)	4.47	4.70	4.79
h (dielectric height)	31	31	31 mils
w (line width)	25	25	25 mils
t (Copper thickness)	0.75	0.75	0.75 mils 1/2 oz. Cu
OTOROLA MECL SYSTEM DESIGN			
w/(b-t) < 0.35	0.83	0.83	0.83
t/b < 0.25	0.02	0.02	0.02
Motorola Equation Valid?	Maybe Not	Maybe Not	Maybe Not
zo (Motorola MECL)	49.61	48.40	47.89 •
S.B. Cohn, J.F. White			
=w/(2*b) <0.35 Narrow, >= 0.35 Wide	0.40	0.40	0.40
White,Cohn Narrow or Wide?	Wide	Wide	Wide
zo (White,Cohn)	51.33	50.03	49.84 •

OTHER COMBINATIONS OF (h,w) (13,10), (19,15), (25,20), (31,25)

New model w/ coupling between channels (for isolation sims)

for two neighboring 3μm spaced lines



for a stripline of general width

$b \updownarrow \boxed{\leftrightarrow w} \updownarrow t$

$$C_f' = \frac{.0885\varepsilon}{\pi}\left[\frac{2}{1-t/b}\ln\left\{1+\frac{1}{1-t/b}\right\} - \left(\frac{1}{1-t/b}-1\right)\ln\left(\frac{1}{(1-t/b)^2}-1\right)\right]$$

this is the added fringe capacitance not C so L not correct below

pF/cm

$t/b = .85/3.2 = .265 \qquad \frac{1}{1-t/b} = 1.36$

$$C_f' = \frac{.0885\varepsilon}{\pi}\left[(2.72)(.858) - (.36)(-.162)\right] \text{ pF/cm}$$

$= 67.37\varepsilon \times 10^{-3}$ pF/cm $= (262.7 \times 10^{-3}$ pF/cm$)\left(\frac{1\text{cm}}{10^4 \mu\text{m}}\right) = 26.3\times 10^{-6}$ pF/μm

$= 26.2$ aF/μm $= \boxed{.0262 \text{ fF}/\mu\text{m}}$ ~~seems~~ small, but I guess it's ok. It's only fringe

$$Z_0\sqrt{\varepsilon} = \frac{94.15}{\left(\frac{W/b}{1-t/b}\right) + \frac{C_f'}{.0885\varepsilon_R}} = \frac{94.15}{1.275 + .761} = 46.2$$

C_f' is fringe capacitance, not C

$\boxed{Z_0 = 23.3\Omega}$ w=3μm from three different approaches, get Z_0 = 23, 22, 26. Very close. R. N's program says 24Ω

$= 35\Omega$ for W=1.5μm

$Z_0 = \sqrt{\frac{L}{C}} = 23.3 \qquad \sqrt{\frac{14.2\times10^{-15}}{26.2\times10^{-18}}} = 23.2\Omega$

for two stripline conductors next to each other:

coupling $.27 + .27C_0 = 1 - C_0$

$1.27C_0 = .729$

$C_0 = .574$ — 5dB coupling!

strategy: do the single stripline sims first. On Friday create the coupled stripline model

if we want 60dB isolation

$C_0 = .001 \Rightarrow Z_{00} = 1.001$ (norm)

$Z_{00} = 50.05\Omega$ un-normalized

can't do it. Need walled conductors. Requirement not exactly true. Z_{00} is for differential signals. We should look @ 2 S/E signals, so even mode.

I think C_o assumes a 50Ω system, always
why Z_o has to be close to 50Ω to get good
$C_o = .001$ isolation. May not be true for our case.

$Z_{oe} = 1.001/0.005$ (normalized)
$= 50.05\,\Omega$ μm "

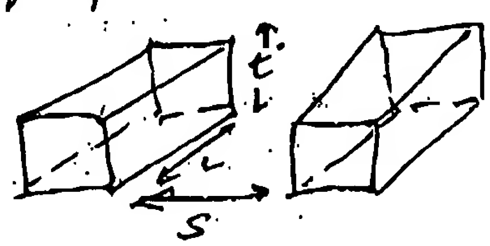
$\sqrt{\varepsilon_r}\, Z_{oe} = 98.8\,\Omega$

$Z_{oe} = 27$ .604 , 22

conclusion: with a 3μm width = W, Z_{oe} is lower than 50Ω, + from the equations, this causes poor coupling in a 50Ω

system ⇒ need a well bt. conductors in 50Ω system, but we're not in a 50Ω system, so what does that mean?

coupling cap $C = \varepsilon_r \varepsilon_0 A/d$

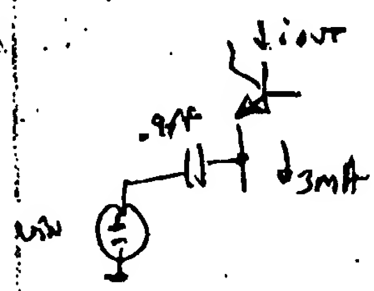


$$C = \varepsilon_0 \varepsilon_r \frac{L t}{S}$$

$S = 3\mu m \quad L = 100\mu m \quad t = .8\mu m$

$$C = (8.85\times10^{-12}\,F/m)(3.9)\left(\frac{1m}{10^6 \mu m}\right)(100\mu m)\frac{(0.85\mu m)}{3\mu m}$$

$$= 978\,aF = .9fF$$



$$\frac{8\Omega}{8\Omega + \frac{1}{2\pi(2\times10^9)(.9fF)}} = \text{coupling} = 98\times10^{-6}$$
$$= -80dB$$

Nick said that if the conductors are ~~far~~ enough away, there's no mutual inductance. Is 3μm far enough?
Billy will need to sim the coupling of microstrip lines on the layout of the IC – that would be better

Tues. 12/08/98
asked Al Reamon to go over sizes on the layout + then we'll call Wayne

Tues. 12/09/98

asked Kelvin to look @ parasitics on one section only. He's doing that.

Nick's calculations for stripline L, C 3 um wide

$v = \frac{c}{\sqrt{\epsilon_r}} = 152 \times 10^6$ m/sec

$v = \frac{1}{\sqrt{LC}}$ where

$Z_0 = 23\Omega = \sqrt{L/C}$ and $152 \times 10^6 \frac{M}{s} = \frac{1}{\sqrt{LC}}$ L, C in units F/um H/um

R_s = 9.96 mΩ/μm Ω/unit length $\mu \delta_s \sigma$

$\frac{\text{sec}}{\frac{\Pi}{\Omega}\cdot\mu m} = \frac{\text{sec}}{\Pi} = \frac{\Omega}{\mu m}$ ok

C = .267 fF/μm × (100 μm) = 26.7 fF

L = .162 pH/μm × (100 μm) = 16.2 pH

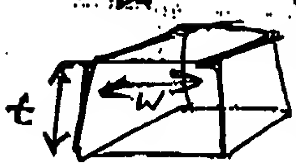
CLOSE

gave to Kelvin, set R = 0

$R_s = \left(\frac{\omega \mu_0 \delta_s}{2}\right)$ δ_s = skin depth = $\sqrt{\frac{2}{\omega \mu_0 \sigma}}$

σ = conductivity of aluminum $\delta_s = \sqrt{\frac{2}{2\pi(2\times10^9 s^{-1})(4\pi\times10^{-7}\frac{H}{m})(3.54\times10^7 \ldots)}}$

δ_s = 1.89 × 10^{-6} meters



$\alpha_c = \frac{R_s}{2}\sqrt{L/C}$

$R_s = 2\pi(2\times10^9 s^{-1})(4\pi\times10^{-7}\frac{H}{m})\left(\frac{1.89\times10^{-6} m}{}\right) = \boxed{14.9 m\Omega}$

Nick said that equation doesn't make sense. 2 Should be able to use σ + the geometry to get R_s/~~length~~ $= \left(\frac{1}{\sigma t w}\right) = \left(\frac{\Omega m}{3.5\times10^7}\right)\left(\frac{10^6 \mu m}{m}\right)\left(\frac{1}{0.85\mu m}\right)\left(\frac{1}{3\mu m}\right) = \boxed{11.2 m\Omega/\mu m}$ length

$\frac{t}{b} = \frac{0.85}{3.2} = .26$

losses $\alpha_d = \frac{\pi\sqrt{\varepsilon_r}}{\lambda_0}\tan\delta = \frac{\pi\sqrt{3.8}(2.0\times10^9 s^{-1})}{(3\times10^8 m/s)}(.006)\left(\frac{m}{10^6 \mu m}\right) = .248\times10^{-6}$ dB/μm

goes in here 12×10^{-6}

$\alpha_c = \frac{R_s \varepsilon_r Z_0}{120\pi(94.15 b)}\left[\frac{1}{1-t/b} + \frac{2 w/b}{(1-t/b)^2} + \frac{(1+t/b)}{\pi(1-t/b)^2}\ln\left(\frac{2-t/b}{t/b}\right)\right]$ NP/μm $= 2.15\times10^{-6}$ dB/μm

1.35 3.4 .73 1.9

α_c = ~~[illegible]~~

α_c = 649 μdB/μm = .000649 dB/μm = 6.5 dB/cm .736 dB/cm

$\frac{NP}{\mu m}\left(\frac{8.686 dB}{NP}\right)$

.1
$\frac{\mu b}{2\times10^6 \mu m}$

Ramon will send Wayne an email + cc: Kent McCormack

Fri. 12/11/98

Stripline analysis continued (redo the $3\mu m$ analysis for $1.5\mu m$ width).

for $W = 1.5\mu m$

$Z_0 = 35\Omega$

$Z_0 = \sqrt{\frac{L}{C}}$ $\quad v = 152 \times 10^6 \frac{m}{s} = \frac{1}{\sqrt{LC}}$

L, C is H/μm, F/μm units

$(35\Omega)^2 = \frac{L}{C}$ $\quad \left(1.52 \times 10^6 \frac{m}{s}\right)^2 = \frac{1}{LC}$

$(35\Omega)^2 C = L \Rightarrow C^2 = \frac{1}{(35\Omega)^2 (152 \times 10^6 m/s)^2} = 187.9 \frac{pF}{m} = .187 fF/\mu m$

$L = 229 fH/\mu m = .23 pH/\mu m$

$R_s = 14.9 m\Omega$ (from 14 pages back) $\quad \delta_s = 1.89 \times 10^{-6} m$ (14 pgs back)

$R = 19.96\ m\Omega/\mu m$

$f_0 = \frac{\omega_0}{2\pi} = \frac{1}{2\pi} \frac{1}{\sqrt{LC}} = 240$ GHz ~~/μm~~ length

$\alpha_d = 2.15 \times 10^{-6}\ dB/\mu m$

$$\alpha_c = \frac{R_s \varepsilon_r Z_0}{120\pi(94.15)b} \left\{ \underset{1.35}{\frac{1}{1-t/b}} + \underset{1.7}{\frac{2\,w/b}{(1-t/b)^2}} + \underset{.73}{\frac{(1+t/b)}{\pi(1-t/b)^2}} \ln\left[\underset{1.8}{\frac{2-t/b}{(t/b)}}\right] \right\} \frac{Np}{\mu m}$$

4.437

$= 80.0 \times 10^{-6}\ Np/\mu m = 695\ \mu dB/\mu m$

$= .000695\ dB/\mu m = 6.95 dB/cm$

8. SUMMARY OF THE INVENTION

A. GIVE A BRIEF DESCRIPTION OF YOUR INVENTION, PARTICULARLY POINTING OUT WHAT IS BELIEVED TO BE NOVEL (THE "HEART" OF WHAT IS NEW).

The requirement for on-chip isolation for the multi-channel RF switch forced the development of true isolated, shielded conductors on-chip, using the multi-layer metal of the SiGe BiCMOS technology. The only process requirement for the realization of the shielded conductor is N > 3 metal layers. However, the fineline geometries of the metal used in the SiGe BiCMOS allowed the thickness and minimum width of the metal conductor to be on the same order, thereby allowing the conductor the ability to have the characteristics of an on-chip coaxial line. Equations were developed to calculate the characteristic impedance of the line, and the inductance and capacitance. This novel structure allows the solution for the Teledesic program to remain monolithic, exceed isolation requirements, and not take up a significant amount of silicon area that would be required to implement the solution using on-chip microstrip or stripline structures. Another unique feature of the concept is to have continuous stacked vias to truly encase the center conductor. This is a key process feature that is a requirement to maintain tight routing while meeting the isolation requirements.

RAYTHEON PROPRIETARY

THIS DOCUMENT CONTAINS PROPRIETARY INFORMATION, AND EXCEPT WITH WRITTEN PERMISSION OF RAYTHEON SYSTEMS COMPANY, SUCH INFORMATION SHALL NOT BE PUBLISHED, OR DISCLOSED TO OTHERS, OR USED FOR ANY PURPOSE, AND THE DOCUMENT SHALL NOT BE DUPLICATED IN WHOLE OR IN PART. THIS LEGEND SHALL BE APPLIED TO ALL DOCUMENTS CONTAINING THIS INFORMATION.

SIGNATURE INVENTOR — DATE 11/18/99

SIGNATURE INVENTOR — DATE 11/16/99

READ AND UNDERSTOOD BY:

KELVIN TRAN — WITNESS NAME (TYPE) — SIGNATURE — DATE 11/16/99

WITNESS NAME (TYPE) — LEONARDO DELA — SIGNATURE — DATE 11/18/99

PATENT DOCKET NO.

99W231

RAYTHEON PATENTS & LICENSING RECEIVED

NOV 17 1999

B. EXPLAIN THE PURPOSE AND ADVANTAGES OF YOUR INVENTION. (WHAT WILL THE INVENTION DO BETTER THAN DONE PREVIOUSLY?)

The advantages of this invention is it provides, for the first time, a truly isolated on-chip coaxial conductor. The prior art for the required performance takes up significant silicon in order to meet the isolation requirement, and this causes an impractical die size when the number of inputs and outputs for the RF switch gets large. The unique solution developed here allows for almost perfect isolation on-chip. This solution comes about as a result of multi-layer metal and the ability to have nearly continuous interlayer metal via stacks along the ground shield walls of the conductor. In the limit, conductors can be spaced at minimum spacing, to a ground plane consisting of all layers of metal with nearly continuous stacked metal vias between the layers. This will allow large M X N matrix arrays to be implemented monolithically ~~and~~ meet the isolation specification while keeping the die size small. Previously, microstrip or stripline structures had to be used on-chip and distance between conductors was the only way to isolate signals. This is due to ~~the fact that the metal technology~~ could not yield ~~long~~ intermetal via structures, it could not yield stacked interlayer metal via structures and most definitely could not yield large numbers of long, stacked interlayer metal via structures. With the yield of today's metal technology, this concept is implementable and yieldable.

RAYTHEON PROPRIETARY

THIS DOCUMENT CONTAINS PROPRIETARY INFORMATION, AND EXCEPT WITH WRITTEN PERMISSION OF RAYTHEON SYSTEMS COMPANY, SUCH INFORMATION SHALL NOT BE PUBLISHED, OR DISCLOSED TO OTHERS, OR USED FOR ANY PURPOSE, AND THE DOCUMENT SHALL NOT BE DUPLICATED IN WHOLE OR IN PART. THIS LEGEND SHALL BE APPLIED TO ALL DOCUMENTS CONTAINING THIS INFORMATION.

SIGNATURE INVENTOR — DATE 11/16/99

SIGNATURE INVENTOR Floyd F. [illegible] — DATE 11/16/99

READ AND UNDERSTOOD BY:

WITNESS NAME (TYPE) Kelvin Tran — SIGNATURE — DATE 11/16/99

WITNESS NAME (TYPE) [illegible] — SIGNATURE — DATE 11/16/99

PATENT DOCKET NO. 99W231

RAYTHEON PATENTS & LICENSING RECEIVED NOV 17 1999

see attached copy of proposal

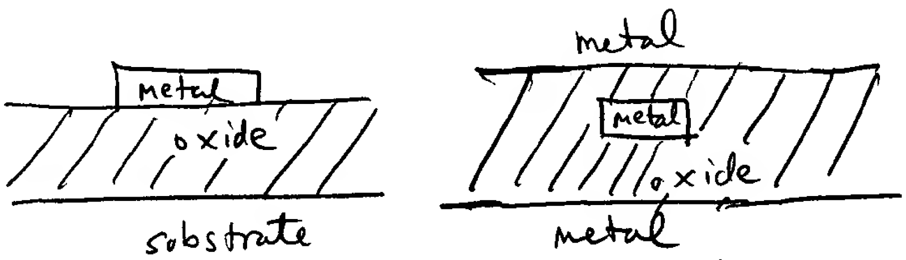
8. SUMMARY OF THE INVENTION *(Continued)*

C. IDENTIFY THE COMPANY PROGRAM OR PRODUCT LINE TO WHICH THE INVENTION APPLIES, AND THE EXPECTED VALUE TO THE PROGRAM OR PRODUCT LINE. ALSO IDENTIFY POTENTIAL COMMERCIAL APPLICATION OF THIS INVENTION, INCLUDING AUTOMOTIVE APPLICATIONS, IF ANY.

The invention was generated as part of the proof-of-concept phase for the Teledesic program for Motorola. If the Raytheon is chosen as part of the competitive bid process the production options will mean $50 - $150M in sales for the company. Also, the Emerging Business Group is seeking outside venture capital to apply the RF switch concept to the cellular Infrastructure Basestation market in the PCS frequency range.

D. IDENTIFY THE PRIOR ART KNOWN TO YOU WHICH IS IMPROVED UPON OR DISPLACED BY YOUR INVENTION, AND STATE IN DETAIL, IF KNOWN, THE DISADVANTAGES OF THE CLOSEST PRIOR ART.

The prior art is the on-chip microstrip and stripline (shown below)



stripline (requires one layer metal) | microstrip (requires 3 layer metal)

During the Teledesic program, these two structures were used to design to the required isolation specifications using the HFSS EM simulator. For either structure, isolation improved only as two neighboring conductors were placed further and further apart. This requires a large amount of silicon area just for routing to guarantee that there is no coupling between channels. Since there are 30 differential inputs and 10 differential outputs on the proof-of-concept IC for Teledesic, this would require a large amount of silicon, based on electromagnetic simulations, in order to guarantee the difficult isolation specification. The solution proposed here provides better isolation performance in a smaller silicon area, with tighter control on the characteristic impedance as a result of the isolation. One of the reasons that previous multi-layer metal (≥3 layers) could not implement the shielded coaxial line on-chip was the inability to allow stacked inter-metal layer vias. Inter layer metal vias were not allowed to be stacked previously due to yield limitations. Modern fabrication technologies have overcome this limitation to enable this unique solution.

RAYTHEON PROPRIETARY

THIS DOCUMENT CONTAINS PROPRIETARY INFORMATION, AND EXCEPT WITH WRITTEN PERMISSION OF RAYTHEON SYSTEMS COMPANY, SUCH INFORMATION SHALL NOT BE PUBLISHED, OR DISCLOSED TO OTHERS, OR USED FOR ANY PURPOSE, AND THE DOCUMENT SHALL NOT BE DUPLICATED IN WHOLE OR IN PART. THIS LEGEND SHALL BE APPLIED TO ALL DOCUMENTS CONTAINING THIS INFORMATION.

SIGNATURE INVENTOR — DATE 11/16/99

SIGNATURE INVENTOR — DATE 11/16/99

READ AND UNDERSTOOD BY:

Kelvin Tran — WITNESS NAME (TYPE) — SIGNATURE — DATE 11/16/99

Leiman Pake — WITNESS NAME (TYPE) — SIGNATURE — DATE 11/11/99

PATENT DOCKET NO. 99W231

RAYTHEON PATENTS & LICENSING RECEIVED NOV 17 1999

9. **DETAILED DESCRIPTION**

DESCRIBE YOUR INVENTION IN DETAIL, USING NECESSARY ADDITIONAL SHEETS
A. BE SURE THAT EACH SHEET IS DATED, AND SIGNED BY EACH INVENTOR AND TWO WITNESSES. (F00299 PAGE 6 SHOULD BE USED, IF PRACTICAL).
B. ATTACH COPIES OF DRAWINGS OR DETAILED REPORTS HELPFUL IN UNDERSTANDING HOW YOUR INVENTION WORKS
C. IF YOUR INVENTION HAS BEEN TESTED, BRIEFLY SUMMARIZED THE TEST RESULTS WHICH CONFIRM THE FUNCTIONS AND ADVANTAGES LISTED IN 8 B ABOVE.

The basic cross-section of the idea is shown on page 8. For the 5 layer metal process, the center conductor (metal 3) is used. This solution allows the minimum impact from parasitics, but also ~~from~~ a symmetry standpoint allows the coaxial solution. For N layers of metal ($N \geq 3$), the conductor should be layer $\left(\frac{N+1}{2}\right)$. The fine geometries of modern-day metal processing technology allows the dimensions of the center conductor to approximate a coaxial line, when shielded as shown on page 7. One of the key enablers to meeting the isolation spec is the stacked, stretched multi-layer vias which allow nearly continuous closure of the center conductor. Some of the features of this structure are briefly described on page 8. Page 9 shows a layout of the RF Switch Proof-of-Concept IC which utilizes this concept. As can be seen from the layout plot, the routes are fairly closely spaced on the layout, with the expected measurement result that the circuit meets the isolation requirement. The long routes on the layout are actually differential lines, which are placed with a common ground plane, as shown on page 8, to help with minimumizing the chip size. As a result of the structure of the coax line, this can be done without compromising isolation. It can be seen from page 9, layout that there are spots in the layout where the shielded coaxial lines (shown as serpentine red structures) are very close to each other without concern for isolation. Although the stacked vias are not continuous, they can be staggered so that the non-continuity is not an issue (see next page). This is for the case where there are two signals that do not share a common ground shield.

RAYTHEON PROPRIETARY

THIS DOCUMENT CONTAINS PROPRIETARY INFORMATION, AND EXCEPT WITH WRITTEN PERMISSION OF RAYTHEON SYSTEMS COMPANY, SUCH INFORMATION SHALL NOT BE PUBLISHED, OR DISCLOSED TO OTHERS, OR USED FOR ANY PURPOSE, AND THE DOCUMENT SHALL NOT BE DUPLICATED IN WHOLE OR IN PART. THIS LEGEND SHALL BE APPLIED TO ALL DOCUMENTS CONTAINING THIS INFORMATION.

SIGNATURE INVENTOR — DATE 11/16/99

SIGNATURE INVENTOR — DATE 11/16/99

READ AND UNDERSTOOD BY:

Kelvin Tran — WITNESS NAME (TYPE) — SIGNATURE — DATE 11/16/99

WITNESS NAME (TYPE) — SIGNATURE — DATE 11/16/99

PATENT DOCKET NO.

99W231

RAYTHEON PATENTS & LICENSING RECEIVED

NOV 17 1999

top view

By staggering the interlayer metal via stacks, there is never a spot in the routes where there is direct coupling between conductors. By slightly increasing spacing between ground shields, isolation further improves. An example of a three layer coaxial line is shown on page 10. This structure allows signal routing above the shield for N > 3 metal layer process. Page 11 is an example of a fully enclosed 50Ω termination within a 5 layer coaxial line. The top and bottom layers are ground plane for full shielding including any bondwire magnetic coupling. As part of the process of looking at prior art versus the new concept, an EXCEL spreadsheet was developed. This program calculated characteristic impedance as a function of geometries of metal and helped to model the coaxial line for HSPICE based simulations to verify performance over BW.

RAYTHEON PROPRIETARY

THIS DOCUMENT CONTAINS PROPRIETARY INFORMATION, AND EXCEPT WITH WRITTEN PERMISSION OF RAYTHEON SYSTEMS COMPANY, SUCH INFORMATION SHALL NOT BE PUBLISHED, OR DISCLOSED TO OTHERS, OR USED FOR ANY PURPOSE, AND THE DOCUMENT SHALL NOT BE DUPLICATED IN WHOLE OR IN PART. THIS LEGEND SHALL BE APPLIED TO ALL DOCUMENTS CONTAINING THIS INFORMATION.

SIGNATURE INVENTOR — DATE 11/16/99

SIGNATURE INVENTOR — DATE 11/16/99

READ AND UNDERSTOOD BY:

Kelvin Tran — WITNESS NAME (TYPE) — SIGNATURE — DATE 11/16/99

WITNESS NAME (TYPE) — SIGNATURE — DATE 11/16/99

PATENT DOCKET NO.

99W231

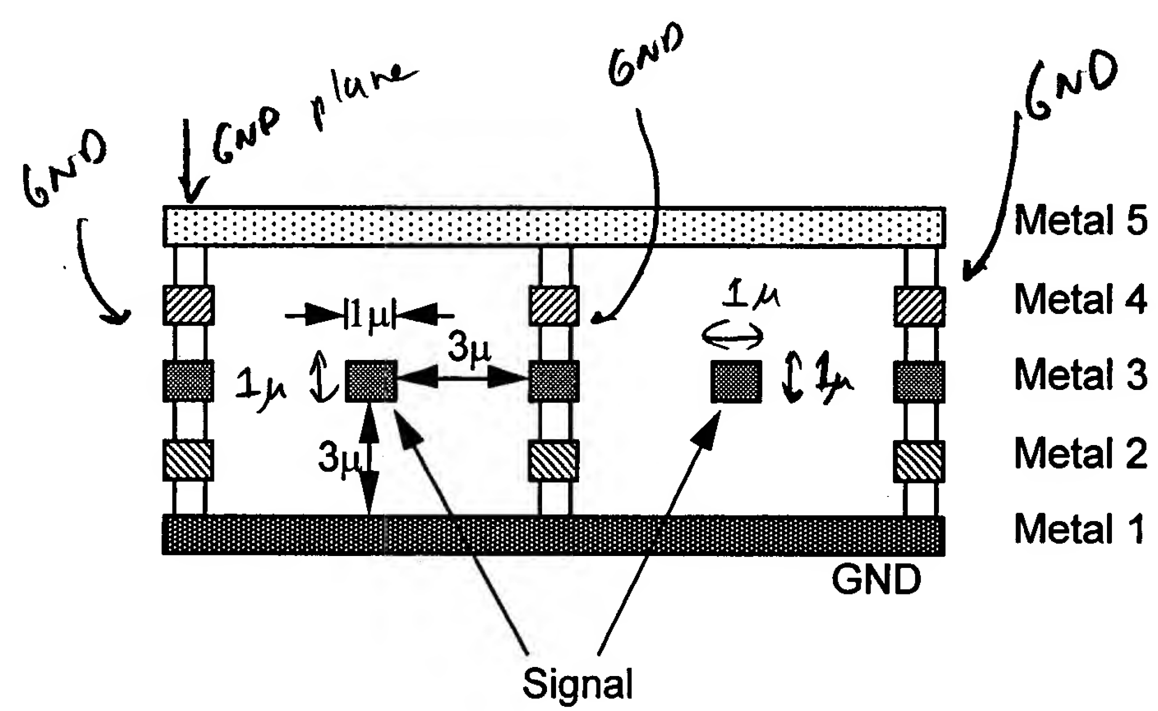
RAYTHEON PATENTS & LICENSING RECEIVED

NOV 17 1999

UNCLASSIFIED

On Chip Transmission Line

- On chip transmission line fabricated with 5 layer metal.
- Grounded shielding provides coax-like characteristic impedance line.
- Grounded shielding provides isolation otherwise unachievable on a small die.

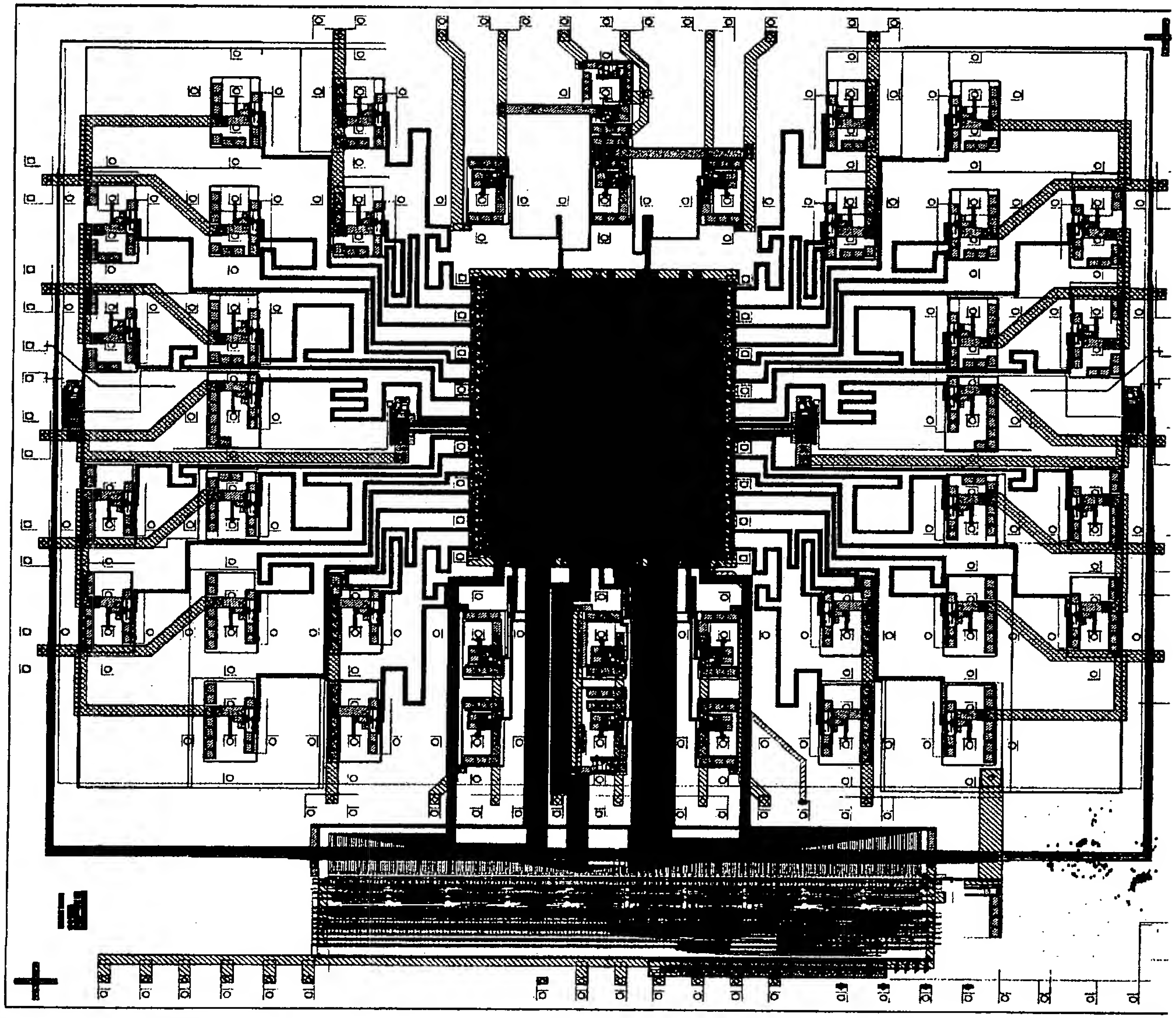


RAYTHEON
PATENTS & LICENSING
RECEIVED
NOV 17 1999

99W231

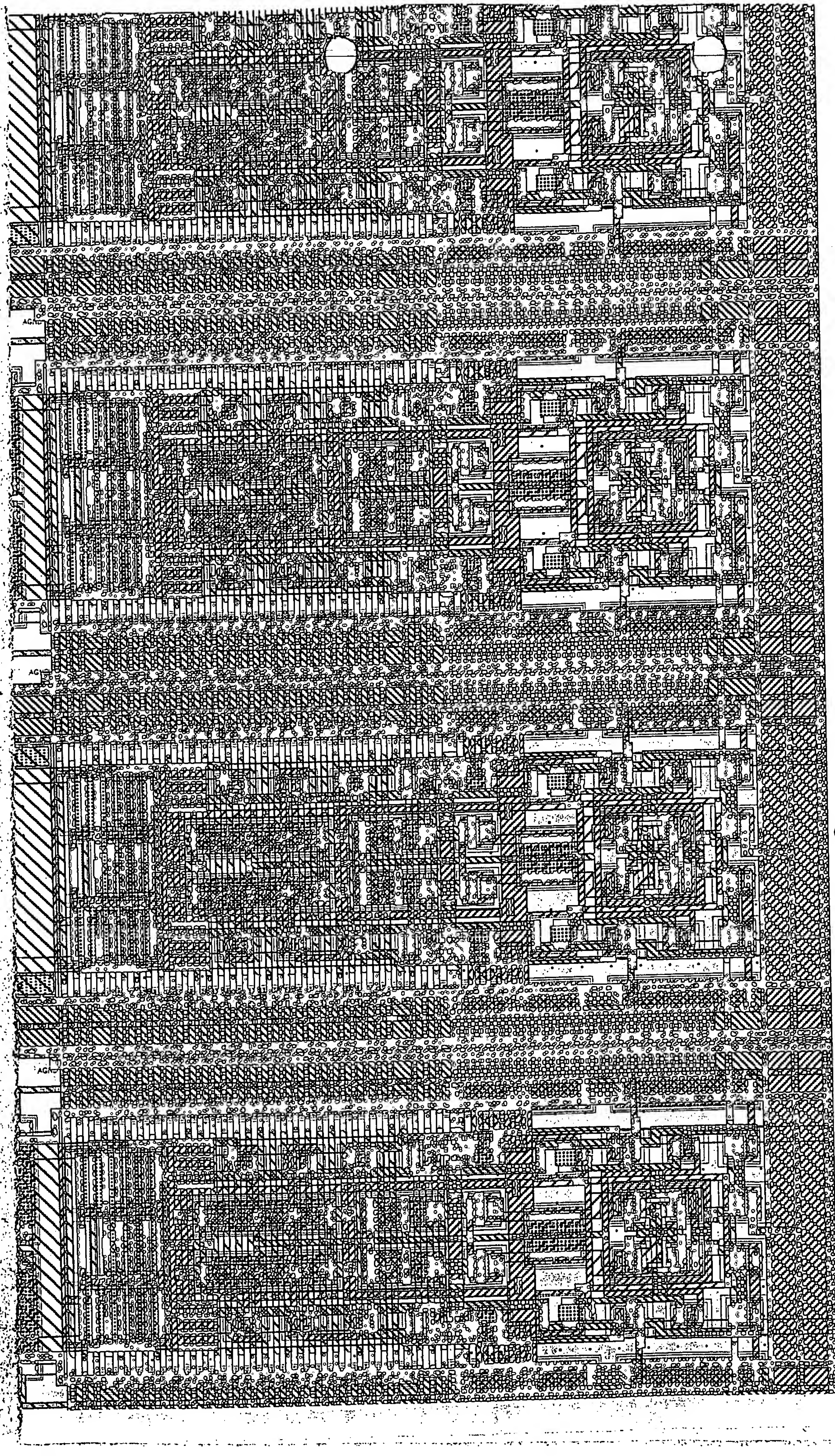
UNCLASSIFIED

IC Layout Plot



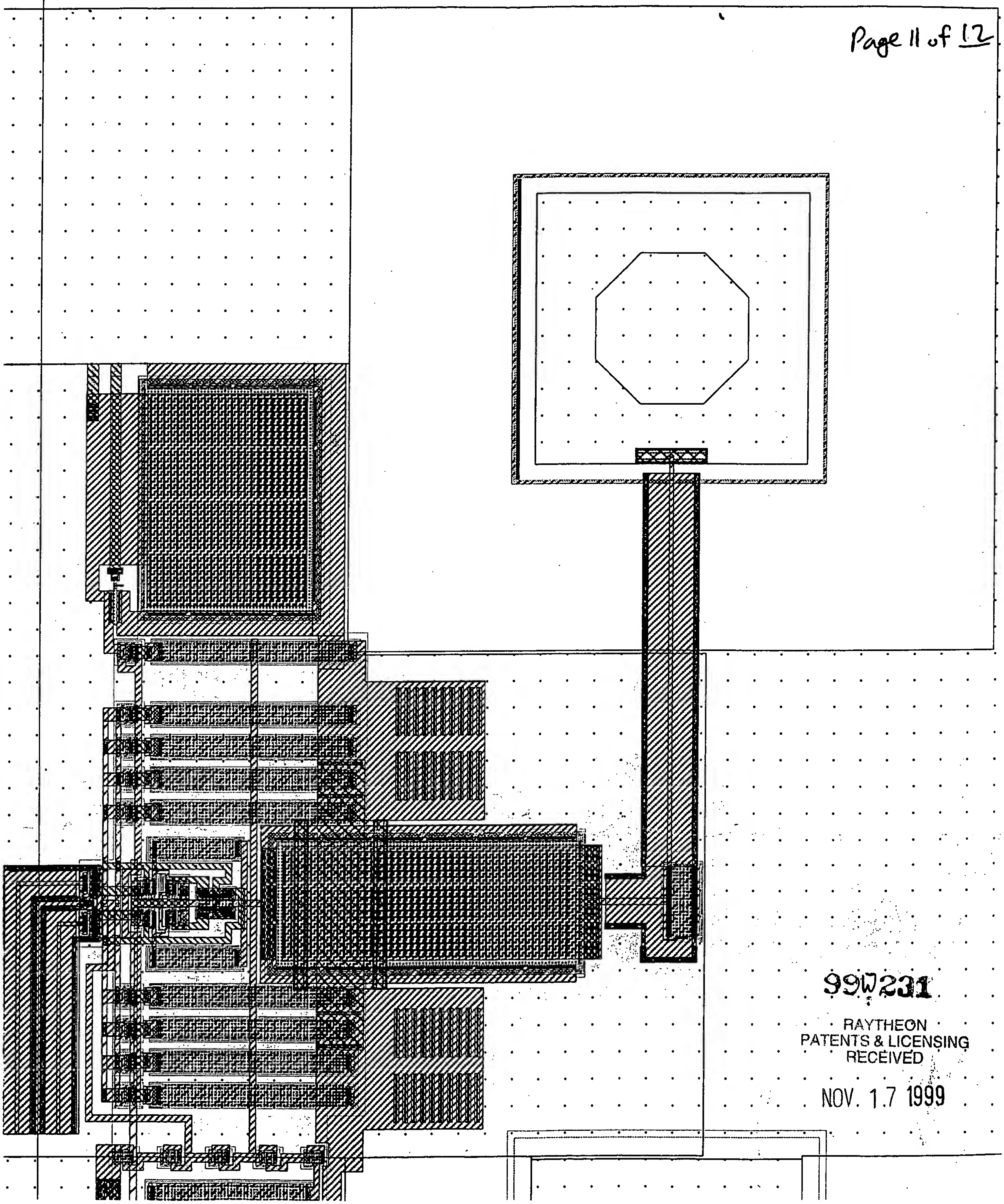
99W231
RAYTHEON
PATENTS & LICENSING
RECEIVED
NOV 17 1999

Page 1 of 12



← 3 layer shield

99W231
RAYTHEON
PATENTS & LICENSING
RECEIVED
NOV 17 1999



99W231
RAYTHEON
PATENTS & LICENSING
RECEIVED
NOV. 17 1999

Assymetric Stripline M125

RowHt	From SiGe 47GHz Process Manual:	Nominal	+/- Tol
41.89	M5	2.07	0.20
24.29		1.2	0.31
17.20	M4	0.85	0.08
24.29		1.2	0.31
17.20	M3	0.85	0.08
24.29		1.2	0.31
17.20	M2	0.85	0.08
24.29		1.2	0.31
12.75	M1	0.63	0.06

Nominals ADD, Tolerances RSS

	For M125:	Nominal	+/- Tol
	M5	2.07	0.20
		5.3	0.55
t	M2	0.85	0.08
h		1.2	0.31
	M1	0.63	0.06

M1, M5 extend far beyond w

b = 7.35 0.64

Program Inputs: **Desired Trace Width (uM)=** **1.5**

I. Symmetric Stripline

	+ErrMax	Nom	-ErrMax
er (SiGe dielectric)	3.90	**3.90**	3.90
h (dielectric height)	1.51	1.2	0.89
w (line width)	1.5	1.5	1.5
t (trace thickness)	0.77	0.85	0.93
MOTOROLA MECL SYSTEM DESIGN			
w/(b-t) < 0.35	2.03	4.29	-37.50
t/b < 0.25	0.51	0.71	1.04
Motorola Equation Valid?	Maybe Not	Maybe Not	Maybe Not
Zo (Motorola MECL)	**39.39**	**33.51**	**26.82**
S.B. COHN, J.F. WHITE			
A=w/(2*b) <0.35 Narrow, >= 0.35 Wide	0.50	0.63	0.84
White,Cohn Narrow or Wide?	Wide	Wide	Wide
Zo (White,Cohn)	**40.02**	**34.46**	**28.15**

OTHER COMBINATIONS OF (h,w) (21,6), (24,7), (27,8), (31,9), (34,10)

w / (b - t) = 0.23
t / b = 0.12

II. Asymmetric Stripline
From Howe: Stripline Ckt Design:p39
s / 2 = trace center to (b/2) {equal} point

Asymmetry Calcs:	+ErrMax	Nom	-ErrMax
w =	1.50	1.50	1.50
wnew =	1.67	1.63	1.59
t =	0.77	0.85	0.93
b =	7.99	7.35	6.71
s =	4.10	4.10	4.10
b+s =	12.09	11.45	10.81
b - s =	3.89	3.25	2.61
1- (t/(b-s)) =	0.80	0.74	0.64
1- (t / (b+s))=	0.94	0.93	0.91
[1- (t/(b-s))]^2 =	0.64	0.55	0.42
[1- (t / (b+s))]^2=	0.88	0.86	0.84
(1 / Pi) =	0.32	0.32	0.32
n = free space impedance =	376.70	376.70	376.70
e = Er of SiGe =	3.90	3.90	3.90
For (w/(b-t))<0.35:			
Wnew/b = (0.07(1-(t/b))+(w/b))/1.2 =	0.21	0.22	0.24
cp1/e = 2wnew/(b-s-t) =	1.07	1.36	1.88
cp2/e = 2wnew/(b+s-t) =	0.30	0.31	0.32
cf1/e = (eq 2-11)	0.69	0.76	0.87
cf2/e = (eq 2-12)	0.54	0.55	0.56
(c/e) tot = cp1/e + cp2/e +2cf1/e + 2cf2/e =	3.82	4.28	5.06
Z0 = n * (1 / (c/e tot)) / sqrt(Er) =	**49.94**	**44.56**	**37.67**

Symmetric b = 2h + t

	Default
Asymmetric:	Symmetric
7.35	3.25
4.10	0

From SiGe Manual: rho(M2) =rho(M3)

	Nom	tol	
rho =	**0.045**	**0.01**	**ohms/sq**

res per unit Length = rho/w

Equations:
1. (Z0)^2 = L / C
2. (s^2) / Er = 1 / LC; where s = speed of light, Er is epsilon rel

Therefore:
1. L = Z0 * sqrt(Er) / s   s = 2.9979E+08 meter/sec
2. C = sqrt(Er) / (s * Z0)

	+ErrMax	Nom	-ErrMax	
Asmmetric Z0	**49.943**	**44.557**	**37.671**	
L =	**0.329**	**0.294**	**0.248**	**pH/uM**
C =	**0.132**	**0.148**	**0.175**	**fF/uM**
R =	**36.667**	**30.000**	**23.333**	**mOhm/uM**

III. Microstrip Calcs:	+ErrMax	Nom	-ErrMax
er (SiGe dielectric)	3.90	**3.90**	3.90
h (line to ground plane spacing)	1.51	1.2	0.89
w (line width)	1.5	1.5	1.5
t (trace thickness)	0.77	0.85	0.93
MOTOROLA MECL SYSTEM DESIGN			
Zo (Motorola MECL)	**57.48**	**47.30**	**34.57**

99W231

RAYTHEON
PATENTS & LICENSING
RECEIVED

NOV 17 1999

This Page is Inserted by IFW Indexing and Scanning Operations and is not part of the Official Record

BEST AVAILABLE IMAGES

Defective images within this document are accurate representations of the original documents submitted by the applicant.

Defects in the images include but are not limited to the items checked:

- ☒ BLACK BORDERS
- ☐ IMAGE CUT OFF AT TOP, BOTTOM OR SIDES
- ☐ FADED TEXT OR DRAWING
- ☐ BLURRED OR ILLEGIBLE TEXT OR DRAWING
- ☐ SKEWED/SLANTED IMAGES
- ☐ COLOR OR BLACK AND WHITE PHOTOGRAPHS
- ☐ GRAY SCALE DOCUMENTS
- ☐ LINES OR MARKS ON ORIGINAL DOCUMENT
- ☐ REFERENCE(S) OR EXHIBIT(S) SUBMITTED ARE POOR QUALITY
- ☐ OTHER: ______________________________

IMAGES ARE BEST AVAILABLE COPY.
As rescanning these documents will not correct the image problems checked, please do not report these problems to the IFW Image Problem Mailbox.